Durability Improvements Through Degradation Mechanism Studies

Fuel Cell Technologies 2009 Kickoff Meeting

September 30-October 1, 2009
DOE Forrestal Building

Presented by: Rod Borup
LANL: Rangachary Mukundan, John Davey, Andrea Labouriau, Roger Lujan, Bo Li, Dusan Spernjak
ANL:Rajesh Ahluwalia, Xiaohua Wang
Ballard: Sylvia Wessel, Paul Beattie, Greg James, Daniel Ramrus, Svetlana Loif, Warren Williams
Ion Power: Steve Grot, Walter Grot
LBNL: Adam Weber
ORNL: Karren More, Mike Brady
UNM: Kateryna Artyushkova, Plamen Atanassov

The Institute for Hydrogen and Fuel Cell Research

Los Alamos

Organizations / Partners

- Los Alamos National Lab (LANL)
  - Lead: durability testing and fundamental characterization
- Argonne National Laboratory (ANL)
  - Integrated comprehensive degradation model and model distribution
- Ballard Power Systems (BPS)
  - Fuel cell system testing, stack integration, component interactions, and stack materials
- Ion Power
  - Specialized membranes, Ionomer and MEAs
- Lawrence Berkeley National Laboratory (LBNL)
  - Fundamental modeling
- Oak Ridge National Laboratory (ORNL)
  - Characterization (TEM) and metal bipolar plates
- University of New Mexico (UNM)
  - Characterization (XPS) and carbon corrosion measurements

Budget

DOE Cost Share	Recipient Cost Share	TOTAL
$8,225,000	$501,263	$8,726,263
94%	6%	100%

YR 1	YR 2	YR 3	YR 4	CUMULATIVE
$2000k	$2000k	$2175k	$2050k	$8225k

	FY09-10 (Year 1)
LANL	$725k
Industrial + Univ. Partners (Ballard, Ion Power, UNM)	$425k
Other National Labs (ANL, LBNL, ORNL)	$850k
FY09-FY10 Total	$2000k

Objectives

- Identification and delineation of individual component degradation mechanisms
- Development of advanced in situ and ex situ characterization techniques for analysis of fuel cell component degradation
- Quantify the influence of inter-relational operating environment between different fuel cell components
- Degradation measurements of components and component interfaces
- Elucidation of component interactions, interfaces, operating conditions leading to cell degradation
- Individual degradation models of all fuel cell components
- Development and public dissemination of an integrated comprehensive model of cell degradation
- Methods to mitigate degradation of components

Technical Targets/Barriers

Table 3.4.3 Technical Targets: 80-kW$_e$ (net) Transportation Fuel Cell Stacks Operating on Direct Hydrogen [a]					
Characteristic	Units	2003 Status	2005 Status	2010	2015
Durability with cycling	hours	N/A	2,000 [g]	5,000 [h]	5,000 [h]
Transient response (time for 10% to 90% of rated power)	seconds	<3	1	1	1
Unassisted start from low temperature [j]	ºC	N/A	-20	-40	-40

Table 3.4.5 Technical Targets: Stationary PEM Fuel Cell Stack Systems (5-250 kW) Operating on Reformate [a]			
Characteristic	Units	2005 Status [b]	2011
Durability	hours	20,000	40,000
Survivability (min and max ambient temperature)	ºC ºC	-25 +40	-35 +40

Durability	**Hours**	**5,000**
	Start /Stop Cycles	**17,000**
	Frozen	**1,650**
	Load Cycles	**1,200,000**

Degradation Mechanism Studies Timeline

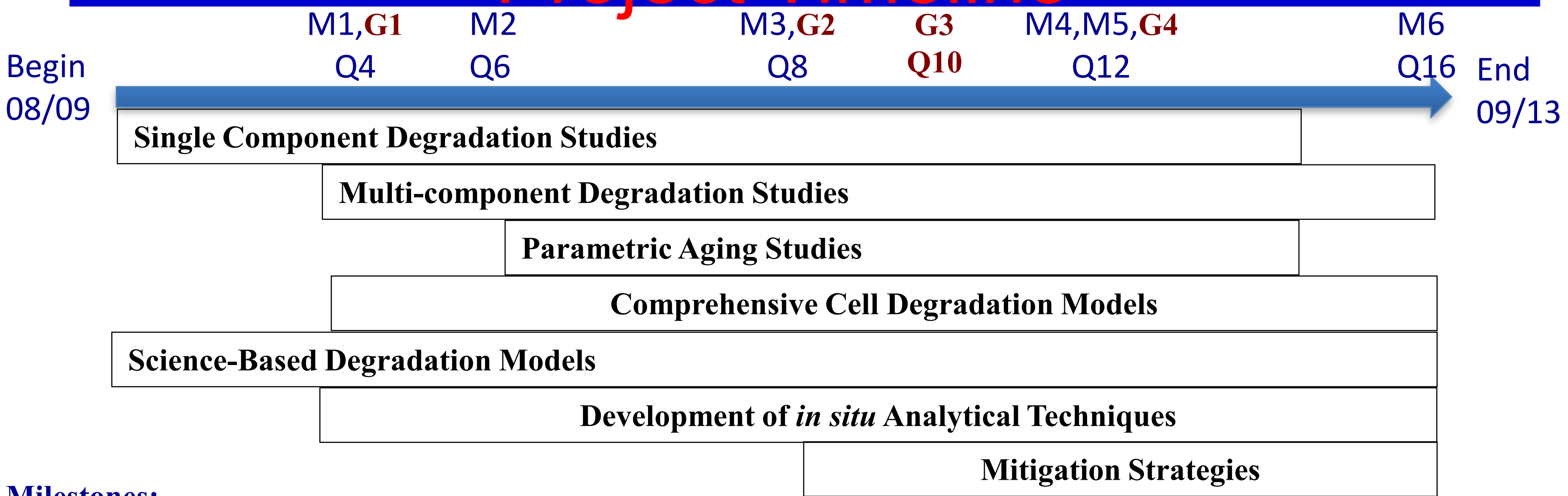
Project initiated in September 2009 for 4 years

Task Timeline Schedule: Quarters (Q) with Milestones (M) and Decision Points (G)

Q Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1a (i) (Ion Pr/LANL)								G								
1a (ii - iv) (LANL)				M						M		G				
1a (v – vi) (BPS)				G		M		M				M				M
1b (LANL)						M				M						
1c (LANL)								M		G		M		M		
1d (UNM / LANL)								M				M				M
2a (LANL)						M						M		M		
2b (LANL)								M		M		M				
2c (LANL)										M						
3a – b (LANL)						M									M	
3c – g (LANL)				M				M	G		M	M			M	M
4a (LBNL)								M								
4b (LBNL)												M				
4c (LBNL)															M	
5a (ANL)												M				
5b (ANL)														M		
5c (ANL)																M
5d (ANL)														G		M

Degradation Mechanism Studies Timeline

Project Timeline



Milestones:

M1: LANL/UNM: Definition of surface functional groups on aged GDLs

M2: LANL/BPS: Identification of component impurities from seals and bipolar plates

M3: Ion Power/LANL RH/potential effect on chemical and mechanical stabilized ionomers.

M4: LANL: Completion of drive cycle (load) life testing with start-up/shut-down

M5: ANL: Completion of individual degradation models

M6: ANL: Distribution of integrated cell degradation model.

Go/No-Go

G1: ORNL: Go/No Go Decision: Plate Resin analysis depending upon acceptable agreement (analysis).

G2: Ion Power/LANL: RH/potential effect on chemical and mechanical stabilized ionomers. Go/No Go: If no new degradation mechanisms over 1000 hrs – conclude membrane AST testing

G3: LANL: X-Ray Tomography to provide resolution ~ < 1 micron pore changes. Go/No: If not able to detect changes in microstructure: conclude the Tomography imaging.

G4: LANL: *in situ* XRD comparison of Pt vs. PtCo ripening. - Go/No Go Decision: EXAFS comparison of Pt vs PtCo

Task Outline

- **Task 1. Elucidation of Single Component Degradation Mechanisms**
  - **Task 1a: Single Component Degradation Studies**
  - **Task 1b: Single Component Interaction Effects**
  - **Task 1c: Microstructure Impact on Durability**
  - **Task 1d: Carbon Degradation (Catalyst Support, GDL/MPL, Bipolar Plates)**
- **Task 2. Elucidation of Multi-component Degradation Mechanisms**
  - **Task 2a: Multi-component studies (full cell degradation testing)**
  - **Task 2b: Multi-component studies**
  - **Task 2c: Component interface studies**
- **Task 3: Parametric Aging Studies**
- **Task 4: Science-Based Degradation Models**
  - **Subtask 4a: Electrocatalyst Degradation**
  - **Subtask 4b: Membrane-Related Cation Degradation Mechanisms**
  - **Subtask 4c: Liquid-Enhanced Degradation Mechanisms**
- **Task 5: Comprehensive Cell Degradation Models**
- **Task 6: Development of *in situ* Analytical Techniques and Mitigation Strategies**

Components Include: Membrane and Ionomer, Catalyst, Catalyst support, Gas Diffusion Layer and Microporous Layer GDL/MPL, Bipolar Plate (<u>Metal & Carbon Based), Seal Materials</u>

Degradation Mechanism Studies Approach

- Fuel cell testing
  - Individual component testing
    - (including controlled environmental aging)
  - Measurements of degradation

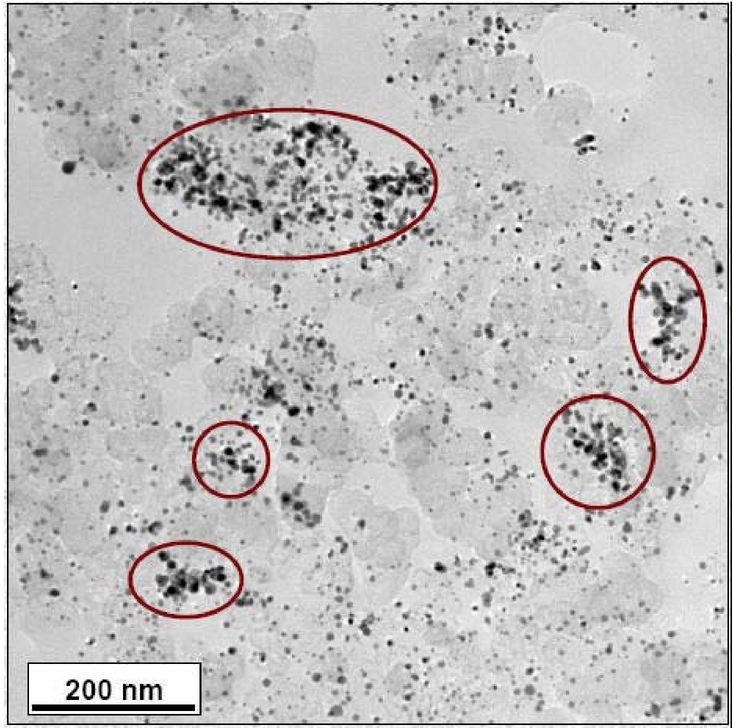
- Characterization
  - Chemical characterization of components
  - Morphological evaluation of components using SEM and TEM.
  - Physical characterization using Hg and H_2O porosimetry, surface energy analysis, contact angle, BET surface area, pore size, pore volume.

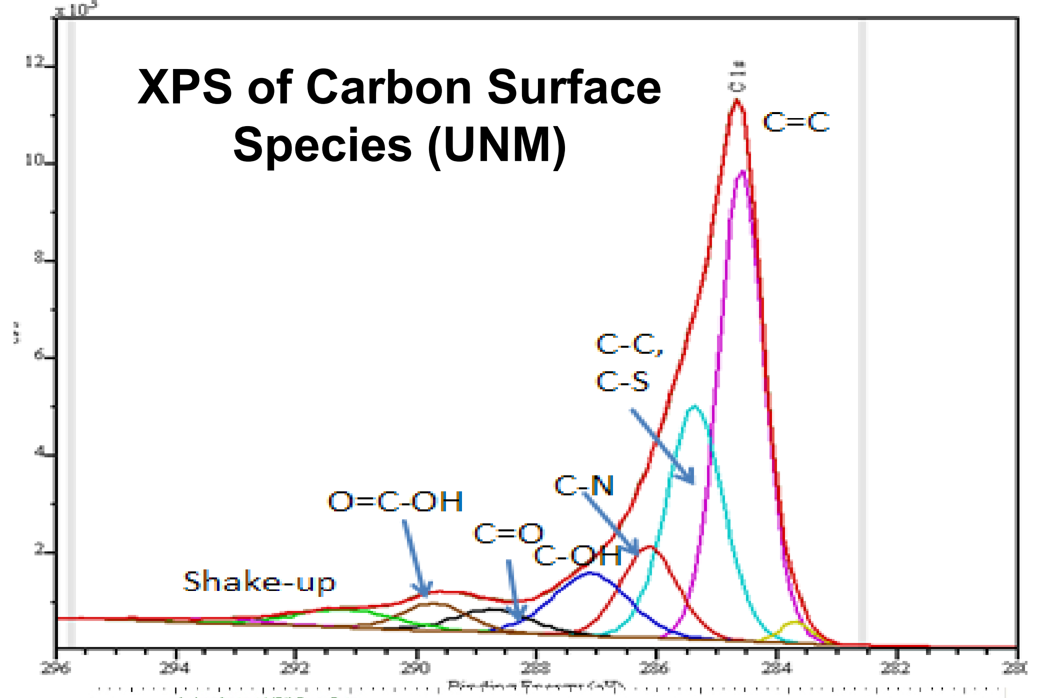
- Modeling
  - Fundamental degradation mechanisms (LBNL)
  - Individual degradation models – kinetic/rate based (ANL)
  - Integrated comprehensive model (ANL)

Characterization Methods to Delineate Degradation Mechanisms

- TEM (Transmission Electron Microscopy)
- X-ray Tomography - Xradia MicroXCT
- Powder XRD (x-ray diffraction)
- SEM/ESEM (Environmental Scanning Electron Microscopy)
- FTIR (ATR, Transmission, DRIFTS)
- Laser Ablation ICP-MS
- XPS – (X-ray Photoelectron Spectroscopy)
- NMR (Solid-state and solution)
- IGC - (Inverse Gas Chromatography)
- TGA/DSC & MS (Thermogravametric Analysis / Differential Scanning Calorimetry)

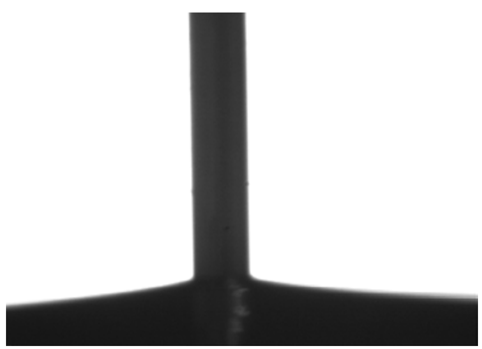
TEM of Catalyst Particle Growth (ORNL)



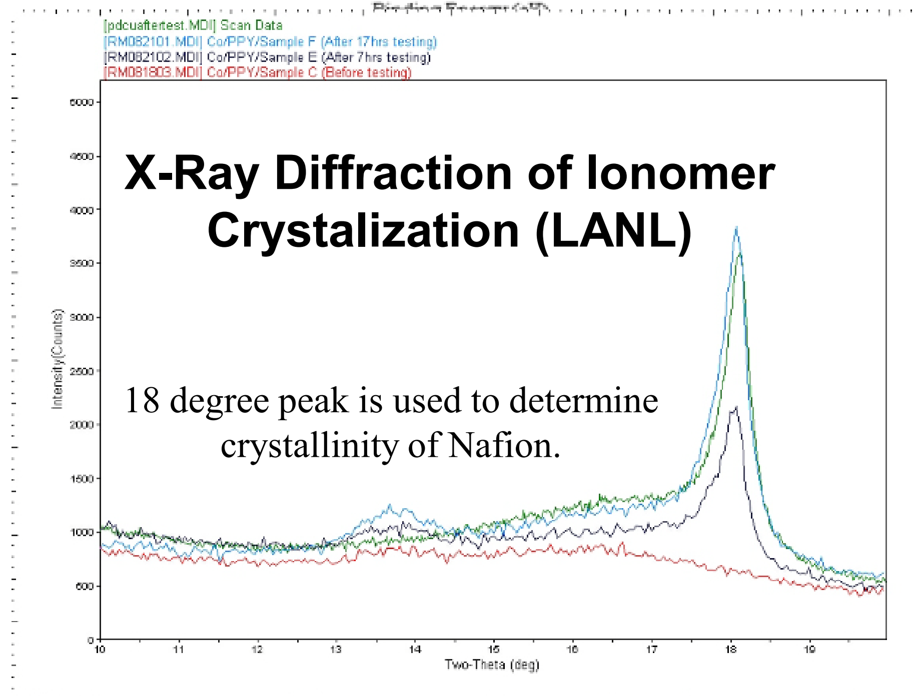


Hydrophobicity Measurements

Unaged #1



Aged



Any inputs/needs

- OEM input on realistic shut-down/start-up protocols and other operating conditions